

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
17 April 2003 (17.04.2003)

PCT

(10) International Publication Number
WO 03/031763 A1

(51) International Patent Classification⁷: **E21B 10/36**,
10/56, 10/56, 10/46

NL-2288 GD Rijswijk (NL). **ZIJSLING, Djurre, Hans**
[NL/NL]; Volmerlaan 8, NL-2288 GD Rijswijk (NL).

(21) International Application Number: PCT/EP02/11064

(22) International Filing Date: 2 October 2002 (02.10.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
01308449.6 3 October 2001 (03.10.2001) EP

(71) Applicant (for all designated States except CA, US): **SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.** [NL/NL]; Carel van Bylandtlaan 30, NL-2596 HR The Hague (NL).

(71) Applicant (for CA only): **SHELL CANADA LIMITED** [CA/CA]; 400 - 4th Avenue S.W., Calgary, Alberta, T2P 2H5 (CA).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **KRIESELS, Petrus, Cornelis** [NL/NL]; Schepersmaat 2, NL-9405 TA Assen (NL). **POLS, Albert, Cornelis** [NL/NL]; Volmerlaan 6,

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

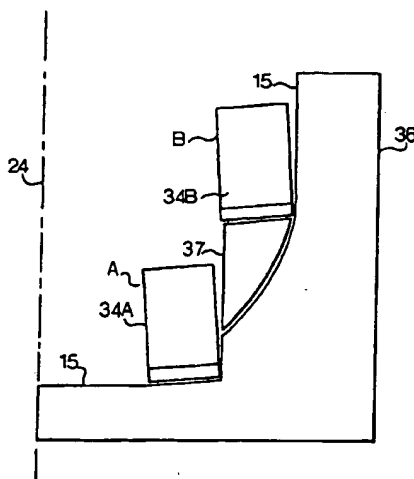
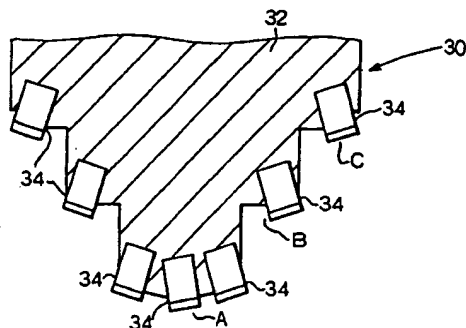
(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SYSTEM FOR ROTARY-PERCUSSION DRILLING IN AN EARTH FORMATION



(57) Abstract: A drilling system for drilling a borehole in an earth formation, comprising a drill string having a central longitudinal (24) axis and being provided with a drill bit (30) having a bottom surface including a plurality of cutters (34) arranged so that said bottom surface has an envelope of a stepped profile in radial direction. First drive means is provided for rotating the drill bit in the borehole so as to induce a scraping movement of the cutters along the borehole bottom (15) and second drive means is provided for inducing a longitudinal reciprocal movement of the drill bit in the borehole so as to induce the cutters to exert a percussion force to the borehole bottom.

BEST AVAILABLE COPY

WO 03/031763 A1

SYSTEM FOR ROTARY-PERCUSSION DRILLING IN AN EARTH FORMATION

The invention relates to a drilling system for drilling a borehole in an earth formation using a drill string having a central longitudinal axis and provided with a drill bit having a bottom surface including a plurality of cutters. Generally there are two basic types of drilling systems, one being the rotational type whereby the drill bit is provided with relative sharp cutters which scrape along the borehole bottom, and the other being the percussion type which generally includes a hammer mechanism that delivers mechanical impacts to the rock formation via the drill bit.

Drill bits traditionally used in percussion drilling have hemispherical cutters usually made of a hard metal such as Tungsten Carbide, which may be coated with a thin diamond layer. Such cutters are generally referred to as Polycrystalline Diamond Enhanced cutters.

It has been experienced that drilling speed with either percussion type drilling systems or rotational type drilling systems is generally low for drilling into very hard rock material. Rotational type systems have the drawback that the scraping action is insufficient for such to rock materials, and percussion type systems lack durability.

It is therefore an object of the invention to provide an improved drilling system which enables increased drilling speed.

In accordance with the invention there is provided a drilling system for drilling a borehole in an earth formation, comprising:

- a drill string having a central longitudinal axis and being provided with a drill bit having a bottom surface including a plurality of cutters arranged so that said bottom surface has an envelope of a stepped profile in radial direction;

- first drive means for rotating the drill bit in the borehole so as to induce a scraping movement of the cutters along the borehole bottom, and

- second drive means for inducing a longitudinal reciprocal movement of the drill bit in the borehole so as to induce the cutters to exert a percussion force to the borehole bottom.

It is thereby achieved that the stepped profile of the bit bottom envelope creates a stepped profile in the borehole bottom as a result of the rotational movement of the drill bit. The "steps" of the stepped profile form edges which are broken off from the borehole bottom by virtue of the percussion action of the drill bit against the borehole bottom. In this manner relatively large pieces of rock can be removed from the borehole bottom, resulting in increased drilling speed.

Suitably the cutters are arranged in a plurality of circular rows of mutually different diameters, and wherein the top surfaces of cutters in the same row extend at substantially equal axial positions.

Further, it is preferred that the cutters in a first said row and the cutters in a second said row adjacent to the first row have top surfaces at mutually different axial position.

In a preferred embodiment said bottom surface of the drill bit has a convex shape.

Preferably the cutters are Polycrystalline Diamond Compact (PDC) cutter including a shank made of a base

material and a top layer made of a poly-crystalline diamond material.

5 In order to efficiently remove the drill cuttings, it is preferred that the top surface of each cutter has a primary inclination relative to the tangential velocity component of the cutter, the primary inclination being such that the top surface pushes drill cuttings in the direction of rotational movement of the cutter.

10 Drill cuttings removal is further enhanced if the top surface has a secondary inclination relative to the radial direction of the cutter, the secondary inclination being such that the top surface pushes drill cuttings from the rock formation in radially outward or radially inward direction.

15 Suitably the cutter has a back-rake angle of less than 90° , wherein the back-rake angle is defined as the angle between the projection of a line perpendicular to said top surface on a plane defined by the longitudinal direction of the drill string and the direction of the tangential velocity component of the cutter, and a plane perpendicular to said longitudinal direction.

20 Preferably the back-rake is between 30° and 90° , and more preferably between 30° and 75° .

25 Furthermore, it is preferred that the cutter has a side-angle of less than 90° , wherein the side-angle is defined as the angle between the projection of said line perpendicular to the top surface on said plane perpendicular to the longitudinal direction, and said plane defined by the longitudinal direction and the direction of the tangential velocity component of the cutter.

30

The invention will be described hereinafter in more detail and by way of example, with reference to the accompanying drawings in which

Fig. 1 schematically shows a bottom view of a first embodiment of a drill bit for use in the method of the invention;

Fig. 2 schematically shows a side view of a cutter of the drill bit of Fig. 1;

Fig. 3 schematically shows a perspective view of the cutter of Fig. 2, for two different positions of the cutter on the borehole;

Fig. 4 schematically shows a bottom view of a second embodiment of a drill bit for use in the method of the invention;

Fig. 5 schematically shows a longitudinal section of the drill bit of Fig. 4;

Fig. 6 schematically shows two cutters of the second drill bit;

Fig. 7 schematically shows a perspective view of a cutter of a drill bit for use in the method of the invention;

Fig. 8 schematically shows a top view (i.e. a view towards the borehole bottom) of a first arrangement of the cutter of Fig. 7;

Fig. 9 schematically shows a top view (i.e. a view towards the borehole bottom) of a second arrangement of the cutter of Fig. 7;

Fig. 10A schematically shows a bottom view of a third embodiment of a drill bit for use in the method of the invention; and

Fig. 10B schematically shows a longitudinal section of a borehole bottom as drilled with the drill bit of Fig. 10A.

In the Figures like reference numerals relate to like components.

Referring to Fig. 1 there is shown a first embodiment of a drill bit 1 having a bit body 2 provided with a plurality of cutters 4 mutually spaced along the bottom face of the drill bit 1. For the sake of clarity, not each cutter has been indicated by a reference numeral. The bit body 2 is furthermore provided with a number of nozzles 6 and waterways 8 for drilling fluid.

As shown in Fig. 2, each cutter 4 has a shank 10 made of a hard base material such as Tungsten Carbide and a top layer 12 made of a poly-crystalline diamond material. Such cutters are commonly referred to as PDC (Poly-crystalline Diamond Compact) cutters. The top layer 12 has a top surface 14 arranged to contact the borehole bottom 15 during drilling. The cutter 4 is fixed to the bit body at a back-rake angle α of about 70° , wherein the back-rake angle α is defined as the angle between the projection of a line 16 which extends perpendicular to said top surface 14, on a plane defined by the longitudinal axis 24 of the drill bit 1 and the direction of the tangential velocity component 18 of the cutter 4, and a plane 17 perpendicular to the longitudinal direction of the drill bit 1. The angle α can also be defined as a primary inclination of the top surface 14 relative to the tangential velocity component 18 of the cutter, the primary inclination being such that the top surface pushes drill cuttings in the direction of rotational movement of the cutter. In Fig. 2, the combined movement of the cutter 4 as a result of rotational movement and percussion movement of the drill bit 1, is indicated by arrows 20.

In Fig. 3 is shown a perspective view of the cutter 4 for two different positions I and II of the cutter 4 along its path 22 on the borehole bottom 15. Line 24 indicates the axis of rotation of the drill bit 1. Line 24 also defines the direction of translation of the cutter 4 during percussion action of the drill bit 1. Apart from the cutter 4 having a back-rake angle α as indicated for position I, the cutter 4 also has a side-angle β as indicated for position II. The side-angle β is defined as the angle between the projection of line 16 on plane 17, and said plane defined by the longitudinal axis 24 and the direction of the tangential velocity component 18 of the cutter 4. The angle β can also be defined as a secondary inclination relative to the radial direction of the cutter, the secondary inclination being such that the top surface pushes drill cuttings from the rock formation in radially outward or radially inward direction.

During normal use the drill bit 1 is rotated in the borehole and simultaneously translated along the axis of rotation 24. As the bit 1 rotates the cutter 4 has a circular motion around the geometrical centre of the borehole. Through the impacts of a percussion hammer (not shown) incorporated in the drill string, the cutter 4 is also pushed into the rock formation 15 for short periods of time. As a result the cutter 4 engages the rock formation 15 in its forward, and up-and-down motion. The back-rake angle is such that the combined forward and impact induced movement of the cutter 4 substantially results in compressive stresses in the brittle PDC material only. A back-rake angle of between 30 and 90 degrees is suitable. As a result of the arrangement of cutter 4 with back-rake angle α , the top surface 14

pushes the rock cuttings in forward direction so that the cuttings are moved away from the location where the cutter 4 is active. Furthermore, as a result of the arrangement of cutter 4 with side angle β , a side force is generated on the formation and the loose rock cuttings. This side force, which is in radial direction of the drill bit 1, pushes the formation/cuttings away from the centre of the hole towards the outside diameter where the cuttings are picked up by the drilling fluid and transported towards the surface. The side-angle can be positive (as shown in Fig. 3) but may also be negative, in which case the cuttings are pushed towards the centre of the hole. For either a positive or a negative side-angle the cutter 4 will have an increased capability of lifting the rock cuttings from the bottom of the hole by having a ploughing action.

Referring to Figs. 4, 5 and 6 there is shown a second embodiment of a drill bit 30 for use in the method of the invention. The drill bit 30 has a bit body 32 provided with a plurality of cutters 34 mutually spaced along the bottom face of the drill bit 30. For the sake of clarity, not each cutter has been given a reference numeral. The bit body 32 is furthermore provided with a number of nozzles 36 and waterways (not shown) for drilling fluid. The cutters 34 are similar in construction to the cutters 4 of the drill bit 1 referred to hereinbefore.

As shown more clearly in Fig. 5, the cutters 34 are arranged in a number of cutter rows A, B, C which are arranged at mutually different axial positions on the bit body 32 so as to form a stepped arrangement.

In Fig. 6 are shown two adjacent cutters 34A, 34B of respective rows A and B. Furthermore is shown a portion of the rock material of the borehole bottom 15 as cut

with the cutters 34A, 34B. Line 36 indicates a plane along which a portion 37 of the rock material is sheared off. For the purpose of clarity the bit body 32 is not shown in Fig. 6.

5 During normal use of the drill bit 30, each cutter 34 of a lower row removes rock material which is supporting rock material attacked by an adjacent cutter 34 of a higher row. For example, as shown more clearly in Fig. 6, cutter 34A of row A removes rock material which
10 supports rock material attacked by cutter 34B of row B. Through this combined action the rock material 37 below cutter 34B is more sheared-off along line 36. As a result the overall cutting efficiency increases.

15 In Figs. 7, 8 and 9 is shown a cutter 40 of a drill bit (not shown) for use in the method of the invention. The cutter 40 is similar in construction to cutter 4 of the embodiment of Fig. 1, and has a shank 42 of Tungsten Carbide and a top layer 44 of a PDC material. The side-angle β of the cutter 40 is such that a V-shaped groove
20 46 is cut by the cutter 40 in the borehole bottom 15. In a first arrangement (Fig. 8), the cutter has a positive side angle β and zero back-rake angle α . In a second arrangement (Fig. 9), the cutter has a positive side angle β and a positive back-rake angle α . In Figs. 8 and
25 9 the direction of movement of the cutter 40 is indicated by arrow 47.

During normal use of the cutter 40, the drill bit to which the cutter pertains is rotated and simultaneously translated in a percussion mode whereby the cutter 40
30 pushes the rock formation at the borehole bottom 15 radially outwards. Such action enhances the cutting action of the cutter 40 and also facilitates the removal

of rock cuttings from the bottom of the hole by pushing the cuttings towards the outward border of the hole where they are ultimately removed by the drilling fluid.

In Fig. 10A is shown a third embodiment of a drill bit 50 for use in the method of the invention. The drill bit 50 has a bit body 52 provided with a plurality of cutters 54 mutually spaced along the bottom face of the drill bit 50. For the sake of clarity, not each cutter has been indicated by a reference numeral. The bit body 52 is furthermore provided with a number of nozzles (not shown) and waterways (not shown) for drilling fluid. The cutters 54, which are similar in construction to the cutters 4 of the drill bit 1 referred to hereinbefore, are arranged in spiralling rows D, E, F and G. The cutters 54 of a particular spiralling row are set at an increasing or decreasing height. Through this setting the cutters 54 operate in a fashion similar to conventional PDC bits, except that the cutting action is additionally upwards/downwards instead of rotational only. As for a conventional PDC bit the cutting depth of an individual cutter 54 is substantially less than its diameter. The force required to make the cut is delivered by a combination of weight on bit (WOB) from the drill string and the percussive downward blows from the percussion hammer.

In Fig. 10B is shown a stepped borehole bottom profile (in longitudinal section) as drilled with the drill bit 50.

Instead of the side-angle β of the cutter 4 being positive (as indicated in Fig. 3) so that the top surface 14 pushes drill cuttings from the rock formation in radially outward direction, the side-angle β can be

negative so that the top surface 14 pushes drill cuttings from the rock formation in radially inward direction.

Instead of the top surface of the cutter being flat, the cutter can have a hemispherical or other suitable shape.

5

Instead of the drill bit face having a convex shape (as in Fig. 5) the drill bit face can have a concave shape, or a partly convex and partly concave shape.

C L A I M S

1. A drilling system for drilling a borehole in an earth formation, comprising:

- a drill string having a central longitudinal axis and being provided with a drill bit having a bottom surface including a plurality of cutters arranged so that said bottom surface has an envelope of a stepped profile in radial direction;

- first drive means for rotating the drill bit in the borehole so as to induce a scraping movement of the cutters along the borehole bottom, and

- second drive means for inducing a longitudinal reciprocal movement of the drill bit in the borehole so as to induce the cutters to exert a percussion force to the borehole bottom.

2. The drilling system of claim 1, wherein the cutters are arranged in a plurality of circular rows of mutually different diameters, and wherein the top surfaces of cutters in the same row extend at substantially equal axial positions.

3. The drilling system of claim 1 or 2, wherein the cutters in a first said row and the cutters in a second said row adjacent to the first row, have top surfaces at mutually different axial position.

4. The drilling system of any one of claims 1-3, wherein said bottom surface of the drill bit has a convex shape.

5. The drilling system of any one of claims 1-4, wherein each cutter is a Polycrystalline Diamond Compact (PDC) cutter including a shank made of a base material and a top layer made of a poly-crystalline diamond material.

6. The drilling system of anyone of claims 1-5, wherein the top surface of each cutter has a primary inclination relative to the tangential velocity component of the

5 cutter, the primary inclination being such that the top surface pushes drill cuttings in the direction of rotational movement of the cutter.

7. The drilling system of any one of claims 1-6, wherein the top surface of each cutter has a secondary inclination relative to the radial direction of the
10 cutter, the secondary inclination being such that the top surface pushes drill cuttings from the rock formation in radially outward or radially inward direction.

8. The drilling system of any one of claims 1-7, wherein the cutter has a back-rake angle of less than 90°,
15 wherein the back-rake angle is defined as the angle between the projection of a line perpendicular to said top surface on a plane defined by the longitudinal direction of the drill string and the direction of the tangential velocity component of the cutter, and a plane
20 perpendicular to said longitudinal direction.

9. The drilling system of claim 8, wherein said back-rake is between 30° and 90°.

10. The drilling system of claim 9, wherein the back-rake angle is between 30° and 75°.

25 11. The drilling system of any one of claims 1-10, wherein the top surface of each cutter is substantially flat.

12. The drilling system of any one of claims 1-11, wherein each cutter has a V-shaped longitudinal section.

30 13. The drilling system substantially as described hereinbefore, with reference to the drawings.

1/5

Fig.1.

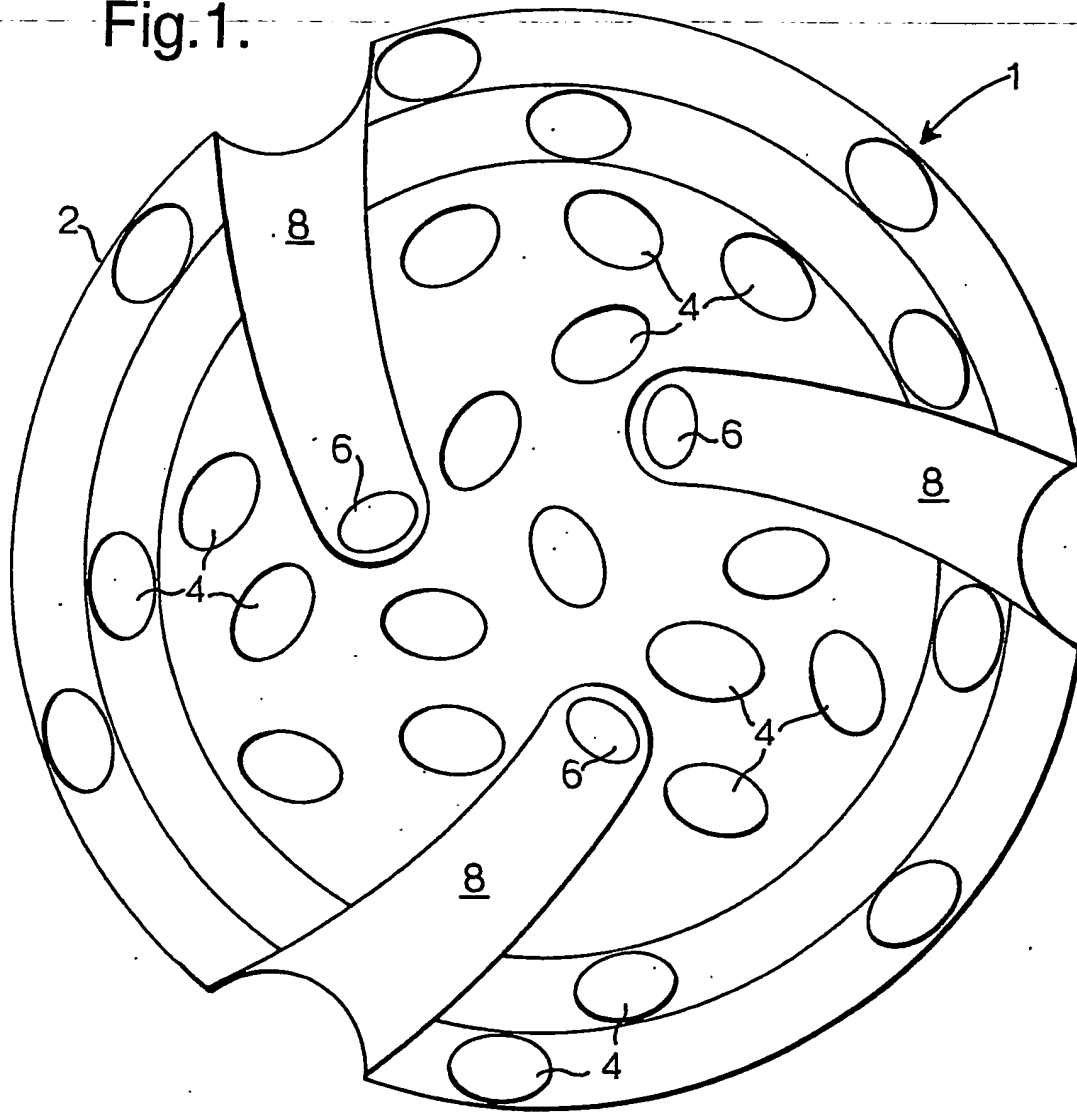
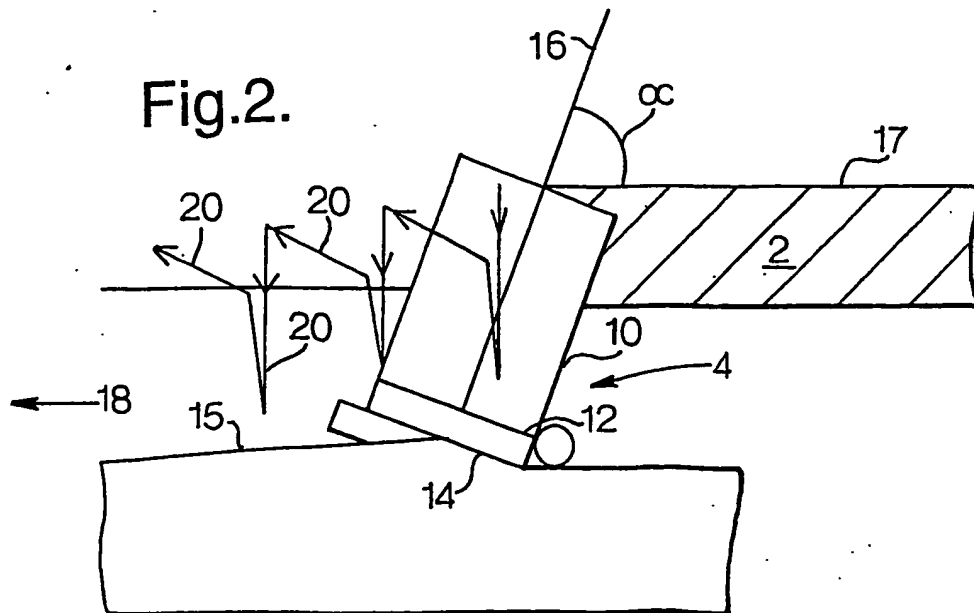


Fig.2.



2/5

Fig.3

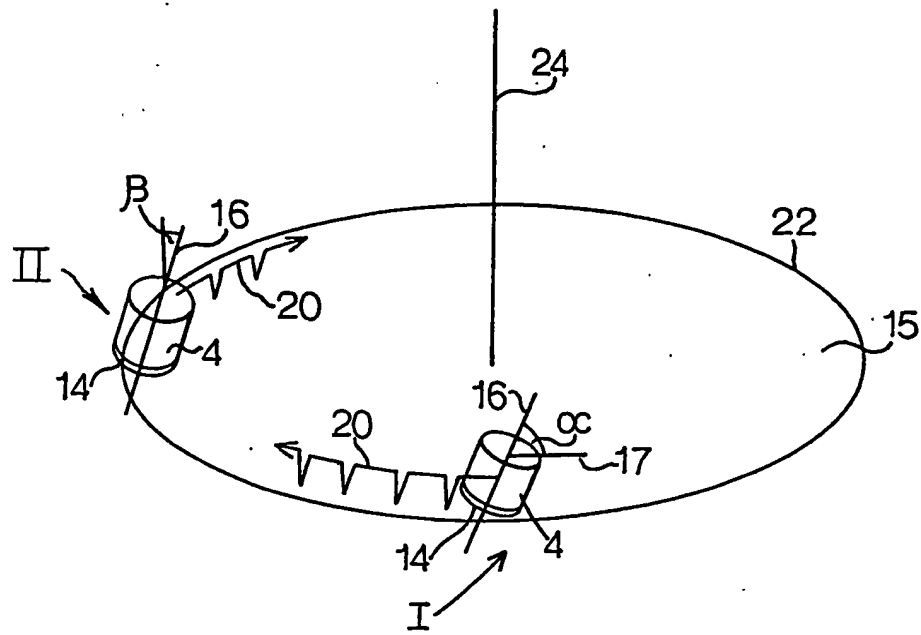
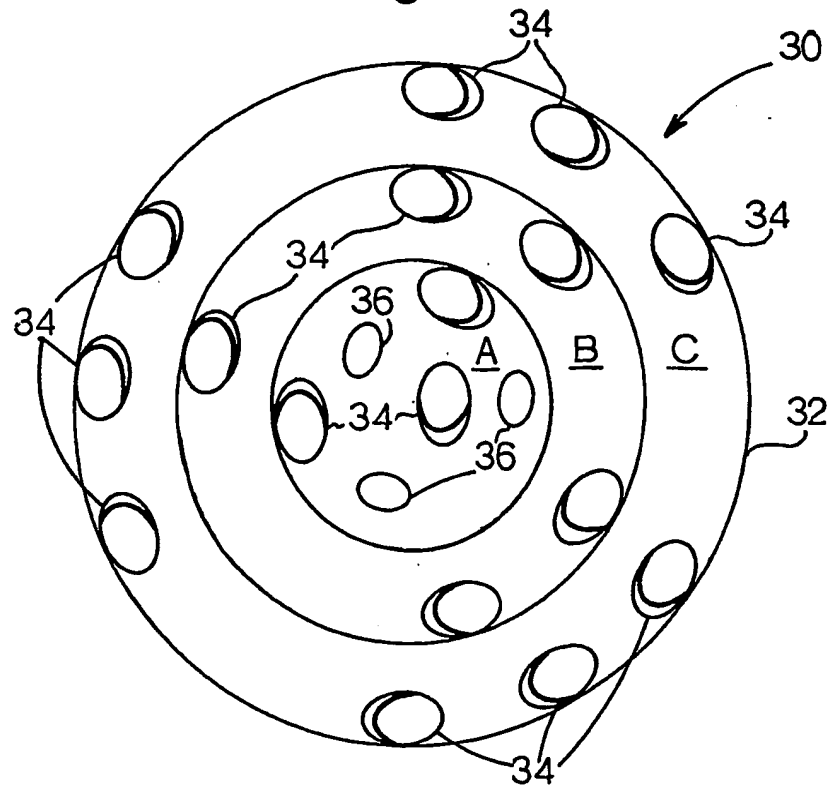


Fig.4.



3/5

Fig.5

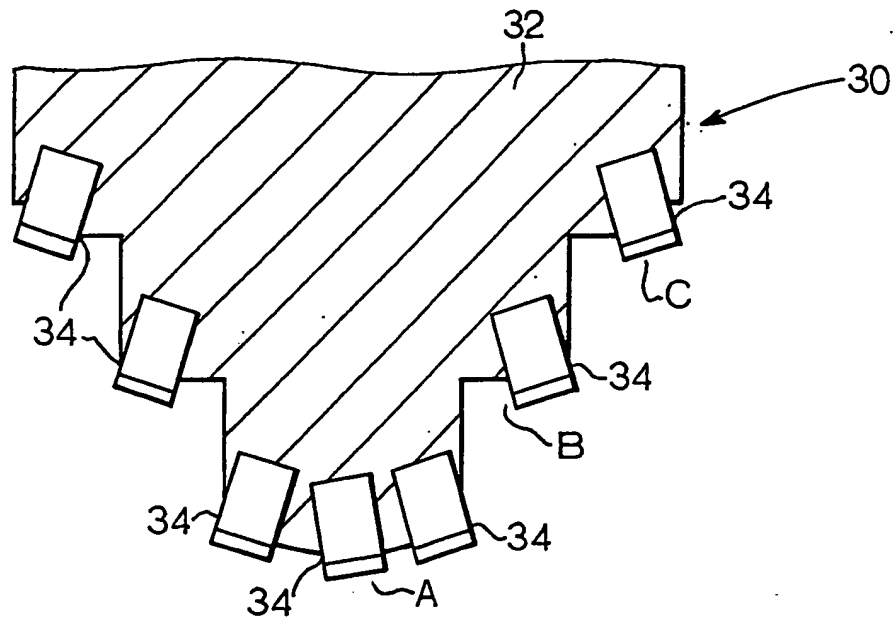
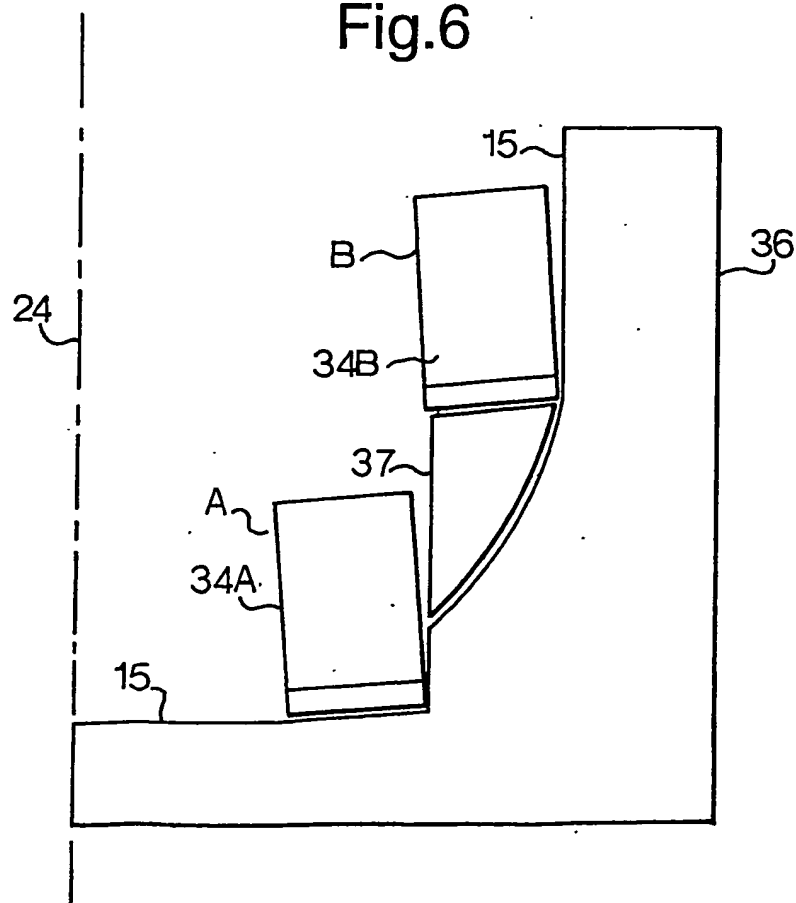


Fig.6



4/5

Fig.7.

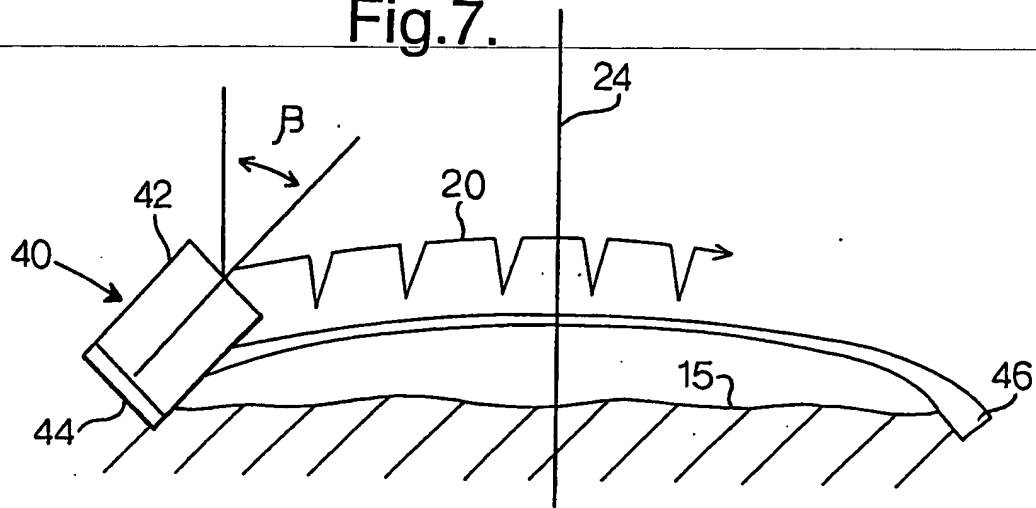


Fig.8.

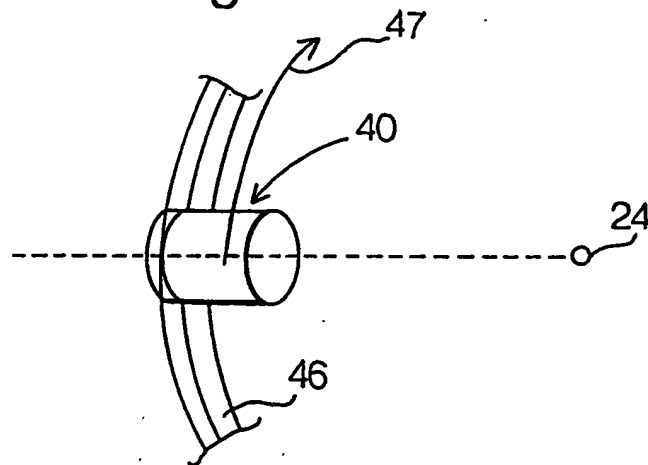
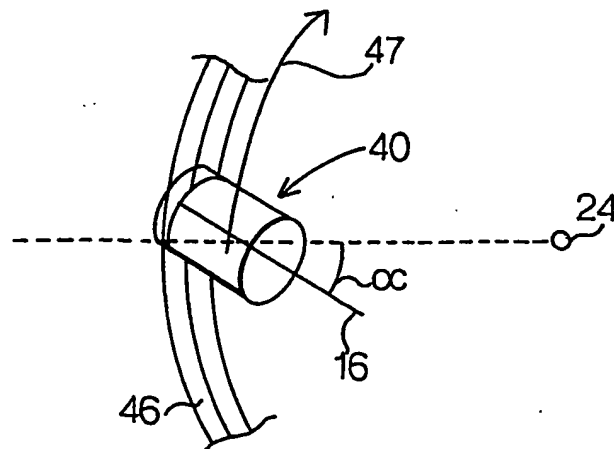


Fig.9.



5/5

Fig.10 a.

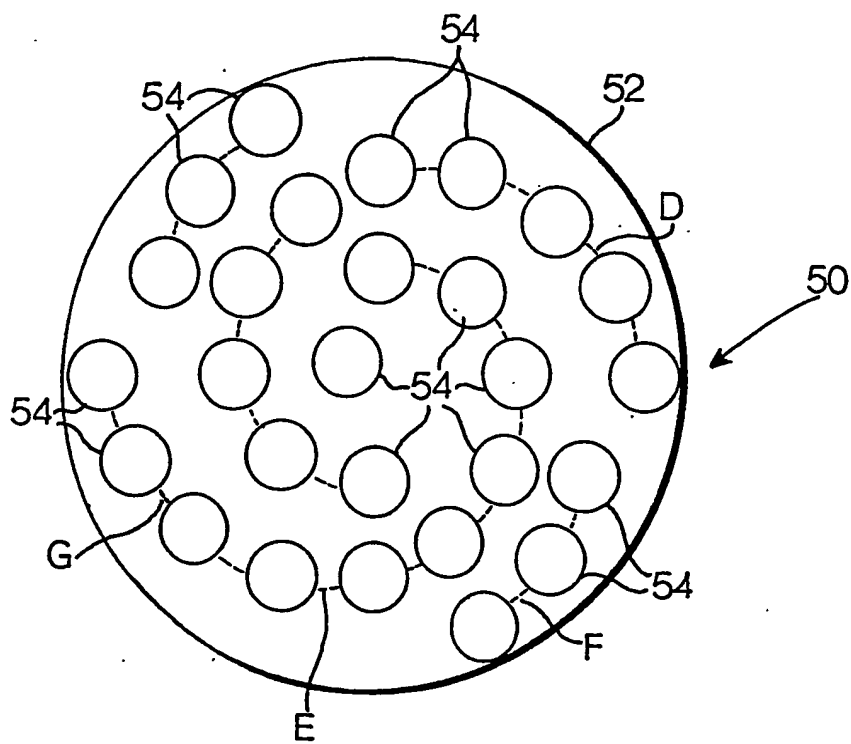
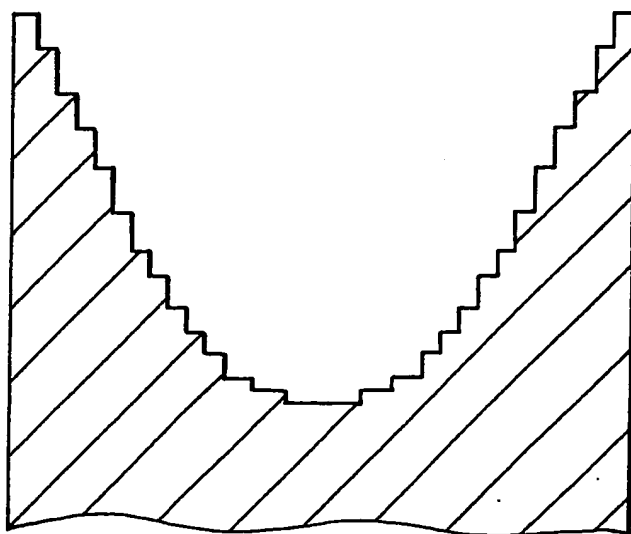


Fig.10b.



INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/11064

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B10/36 E21B10/40 E21B10/56 E21B10/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 648 524 A (DIONISOTTI) 11 August 1953 (1953-08-11) column 3, line 25 - line 41; figures 1-14 column 2, line 23 - line 27	1-4, 11-13
Y	----	5-10
Y	US 4 073 354 A (ROWLEY) 14 February 1978 (1978-02-14) column 4, line 47 - line 50 column 3, line 66 - column 4, line 6 column 4, line 31 - line 34	5-8
Y	US 6 253 864 B1 (HALL) 3 July 2001 (2001-07-03) column 7, line 36 - line 40 claims 10,11 column 7, line 5 - line 40 ----- -/--	9,10

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Z document member of the same patent family

Date of the actual completion of the international search

29 January 2003

Date of mailing of the international search report

05/02/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

SOGNO, M

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/11064

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 914 723 C (FUCHS) 8 July 1954 (1954-07-08) the whole document	1-4, 13
A	GB 758 084 A (DIONISOTTI) 26 September 1956 (1956-09-26) page 1, line 29 - line 59	1-13
A	US 3 321 034 A (WEBB) 23 May 1967 (1967-05-23) the whole document	1-13
A	GB 2 246 151 A (CAMCO DRILLING GROUP LIMITED) 22 January 1992 (1992-01-22) page 15, line 22 -page 16, line 1 page 14, line 11 - line 15; figures 9, 9A page 30, line 18 - line 21 page 28, line 1 - line 12; figure 10	1-13
A	GB 2 345 931 A (BAKER HUGUES INCORPORATED) 26 July 2000 (2000-07-26) abstract; figures 2-4, 11 page 10, line 11 -page 11, line 17	1-13
A	US 4 098 363 A (ROHDE) 4 July 1978 (1978-07-04) column 2, line 64 -column 3, line 9	1-13
A	US 4 200 159 A (PESCHEL) 29 April 1980 (1980-04-29) column 5, line 56 -column 6, line 2	1-13
A	US RE34435 E (WARREN) 9 November 1993 (1993-11-09) the whole document	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 02/11064

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2648524	A	11-08-1953	NONE	
US 4073354	A	14-02-1978	AU 504432 B2	11-10-1979
			AU 2652477 A	04-01-1979
			BE 861223 A1	25-05-1978
			BR 7707321 A	20-06-1978
			CA 1068256 A1	18-12-1979
			DE 2752162 A1	01-06-1978
			FR 2372311 A1	23-06-1978
			GB 1557380 A	05-12-1979
			JP 1047273 C	28-05-1981
			JP 53067601 A	16-06-1978
			JP 55040760 B	20-10-1980
			MX 143362 A	23-04-1981
			NL 7708960 A	30-05-1978
			NO 772422 A	29-05-1978
US 6253864	B1	03-07-2001	NONE	
DE 914723	C	08-07-1954	NONE	
GB 758084	A	26-09-1956	NONE	
US 3321034	A	23-05-1967	NONE	
GB 2246151	A	22-01-1992	AU 8044091 A	23-01-1992
			CA 2047316 A1	18-01-1992
			EP 0467642 A2	22-01-1992
			NO 912794 A	20-01-1992
GB 2345931	A	26-07-2000	US 6338390 B1	15-01-2002
			BE 1013805 A5	03-09-2002
			IT T020000022 A1	11-07-2001
US 4098363	A	04-07-1978	BE 866300 A1	24-10-1978
			DE 2817986 A1	02-11-1978
			FR 2388982 A1	24-11-1978
			GB 1596609 A	26-08-1981
US 4200159	A	29-04-1980	DE 2719330 A1	09-11-1978
			BE 866578 A1	30-10-1978
			CA 1079713 A1	17-06-1980
			FR 2388983 A1	24-11-1978
			GB 1596610 A	26-08-1981
			JP 1476483 C	18-01-1989
			JP 53135802 A	27-11-1978
			JP 57059399 B	14-12-1982
US RE34435	E	09-11-1993	US 4932484 A	12-06-1990
			CN 1046366 A	24-10-1990
			EP 0427816 A1	22-05-1991
			NO 905313 A	07-12-1990
			WO 9012192 A1	18-10-1990

This Page Blank (uspto)

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ **BLACK BORDERS**
- ☒ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☒ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☒ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

This Page Blank (uspto)